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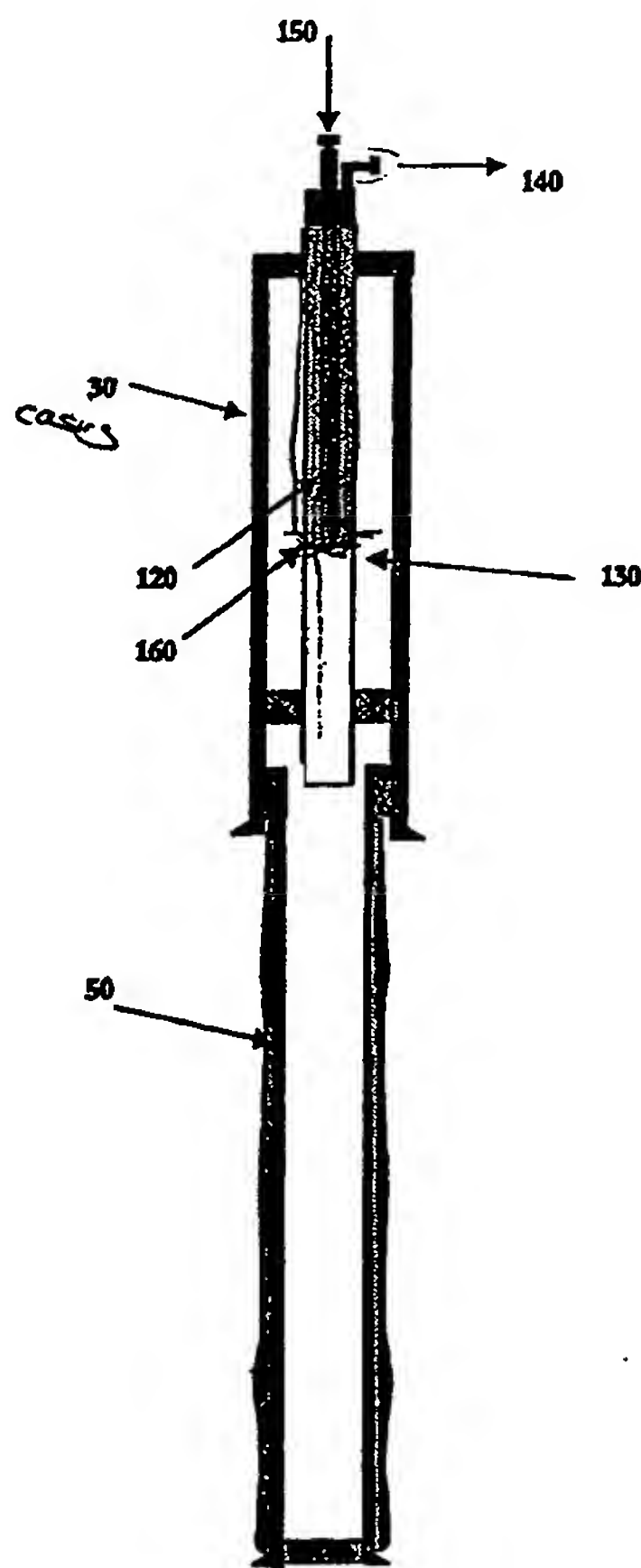
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(54) Title: UNDERBALANCED PERFORATION



(57) Abstract: There is disclosed a method of initiating production of hydrocarbons from a well having a column of liquid to provide a hydrostatic head. The method comprises inserting a tubular member inside a casing to a required depth in the liquid to define a chamber, then sealing the chamber from the outside environment. A gaseous material is then supplied under pressure to the chamber to create a pressure differential between the chamber and the outside environment, and cause the liquid to be displaced and flow along a flow conduit. The displaced liquid is collected and the casing perforated to enable hydrocarbons to flow. An apparatus is provided and includes a tubular member for insertion into the well casing, means for sealing the chamber, gas supply means to supply gas under pressure to the chamber, fluid flow means to allow collection of displaced liquid, and means to perforate the casing.

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UNDERBALANCED PERFORATION

The present invention relates to the extraction of fluids, especially hydrocarbons. A method of removing these hydrocarbons, and apparatus suitable for performing the
5 method, is described hereinafter. The invention finds particular use in the oil and gas industry during the extraction of natural gas or oil from a low pressure reservoir.

Natural reservoirs of hydrocarbons in the form of oil
10 and gas have been exploited commercially with varying degrees of success since the mid- to late nineteenth century. However, the need for a petrochemical industry has steadily and rapidly developed since around 1900 and during this time readily accessible reservoirs at land based sites
15 have been depleted so that currently exploitation is mainly concerned with off-shore, often deep water sites. The need often arises to re-work older sites previously considered as depleted by the technology available at the time the sites were first exploited. The natural drive of these sites may
20 have become exhausted or so weak that though deposits of desirable hydrocarbons remain, the recovery thereof awaits a cost-effective technology.

Extracting hydrocarbons from deep wells or at these previously worked sites requires an artificial lifting
25 system to bring the hydrocarbons to the surface. The system includes pumping means associated with a well head assembly

or "tree" and a riser tubing within a well casing. Poor natural pressure reservoirs may be worked using fluid displacement systems e.g. pumping brine into a reservoir to displace hydrocarbons to surface.

- 5 Care has to be taken for environmental reasons in extracting hydrocarbons. Thus it is essential that any oil production facility can reliably control the output of each well associated therewith. Therefore, it is necessary to have complete control over pressure in the wells.
- 10 Established techniques exist for countering the natural pressure of a reservoir by applying over-pressure relative to the natural reservoir pressure by means of a column of mud or completion fluid in the well.

Reservoir pressure is detectable as a fluid pressure in

15 a borehole or well whenever an oil or gas reservoir has been intercepted by that borehole or well. As a generalisation it is lower than the hydrostatic pressure, or head of drilling fluid (commonly "mud"), and varies with depth, but reservoir pressure is affected by many factors, and may be

20 considerably higher or lower than normal. The hydrostatic head is the pressure exerted by a column of liquid, having a given density, above a point a given distance below. If the hydrostatic column of mud is greater than the reservoir pressure then an overbalance exists. This overbalance keeps

25 the well stable and prevents the hydrocarbon being produced into the well bore.

Consequently, for a well to operate productively, it is necessary to achieve a controllable underbalance of these pressures, i.e. selectively arrange for the reservoir pressure to be greater than the hydrostatic pressure of fluid over the reservoir. It is imperative that this underbalance is achieved in a controlled and safe manner to avoid the potential for hazardous losses of hydrocarbons with attendant risks of endangering personnel and equipment due to fire and explosions, and environmental pollution.

Generally the initial pressure encountered when a borehole first intercepts a reservoir only partly affects the ability of oil or gas to subsequently flow up the completed well: the most important factor being the drive mechanism.

This is well understood by those in the art and much has been written concerning drive mechanisms and techniques for enhancing the natural drive or applying an induced force which is needed to drive oil or gas out of a reservoir and up the well bore. The literature describes many drive mechanisms used in modern well technology including dissolved gas drive, water drive, gas cap drive, gas drive, miscible flooding and gravity drainage. Gas or water pressure is carefully controlled in a pressure maintenance program, so that pressure is just sufficient to drive the hydrocarbons to the surface. A pressure maintenance program might make use of a combination of techniques employed to sustain the natural pressure in a producing well to ensure

continuous production at the required rate. Water drive and gas drive are two practical methods which are frequently used in combination with re-injection mechanisms. Water or gas is then injected through service wells.

5 However, known methods currently applied in the oil and gas industry for enhancing the natural drive of a reservoir or underbalancing wells include using oil base products or a full coiled tubing lift. The use of oil base fluids for this type of operation has the inherent high risks of pollution
10 causing major problems for companies working in environmentally sensitive areas offshore. This inevitably results in production shut downs which have a severe financial impact on the earning potential of the company involved.

15 Conventional methods involving coiled tubing also suffer from inherent problems given the very time-consuming nature of the method. By having to feed lengths of coiled tubing the fully into the well until the reservoir depth has been reached, in some cases 4000 feet or more, many hours of
20 valuable production time have been lost. Added to this is the major cost of maintaining personnel and equipment on standby whilst the coiled tubing is being fed into the well which is still not in production mode as yet. In some instances, times of 36 hours constant feeding of coiled
25 tubing to reach the reservoir depth are not unknown. Such a method is an expensive and time consuming procedure to carry out.

An object of the present invention is to obviate or mitigate at least some or all of the disadvantages of the known underbalance methods and to further improve hydrocarbon production techniques. A further object of the invention is to offer the industry an environmentally acceptable method of underbalancing a well. A still further object of the invention is to provide a tool for use in underbalancing a well which tool is of a relatively simple design, offering advantages in ease of installation and safety.

Accordingly, the present invention provides a method of initiating production of hydrocarbons from a well having a shaft with a casing or lining therein and a flow conduit located within the casing or lining and a hydrostatic head provided by a column of liquid standing over the accessible hydrocarbons in the well, which method comprises:

inserting a tubular member into the well so that it extends into the liquid to a required depth to provide a chamber defined by the tubular member and the liquid and a flow conduit;

sealing the chamber from the outside environment;

causing a gaseous material to flow into the chamber to create a pressure differential between the chamber and the outside environment and so cause the liquid in the well to be displaced and flow along the flow conduit;

collecting the liquid displaced from the well; and

perforating the casing to enable the hydrocarbon to flow.

This enables the well to be underbalanced much quicker than is possible using conventional methods and at a greatly
5 reduced cost. A key feature recognisable in the method is that the steps required to achieve the pressure underbalance adjustments are undertaken "topside" of the well, rather than down at the reservoir depths. Furthermore, the pressure adjustments are achievable using environmentally safe
10 methods utilising gas and fluids which are recoverable within the proposed protocols. Furthermore, the simplicity of the method is recognisable in that the invention selectively substitutes a part of the volume of the fluid standing over the hydrocarbon with a corresponding volume of
15 gas to effect the necessary pressure adjustments. The safety inherent in the method is recognisable in that both the supplied gas, preferably an inert gas like nitrogen, and the displaced fluid, preferably an aqueous completion fluid, are recoverable without loss to ambient, and the thus
20 underbalanced well is thereafter controllable in a manner known in the art.

The displaceable liquid to be used in the underbalance method of the invention may be a typical completion fluid or brine, containing sodium chloride or calcium chloride, for
25 example.

The sealing step may further include cementing the casing in place by filling the annular space between the

casing and the bore hole. This prevents any unwanted fluids entering the annular space.

The gaseous material used may consist of, or include nitrogen.

5 Thus according to the invention, there is provided a method of underbalancing a well which does not have sufficient pressure to provide flow from a reservoir to be tapped, by introduction of a gas to displace fluid from tubing forming part of the well characterised by installing
10 in an upper part of the well tubing remote from the reservoir an underbalance tool having means for pumping fluids separately therethrough and an associated tool tubing of narrower bore than the well tubing and of a pre-selected length capable of penetrating into the well tubing to a pre-
15 determined depth to permit exchange of fluid in the well for gas, locating the tool tubing within the well tubing, operatively connecting the tool and its tubing to permit fluid flow therein, providing a controllable gas supply to said tool, operating the tool to deliver gas and displacing
20 fluid from the well tubing by means of said gas to achieve underbalance.

Such a method is useful at the stage of completion, ideally on new wells with cemented casings or liners, but is applicable whenever the well is in a dead, killed or
25 overbalance status. Thus the method is also applicable for minimising the risks of hydrate formation when a well has been suspended and re-entered. Where the well has been pre-

perforated or uses slotted liners, it is possible to apply the method by utilising the tool in conjunction with a downhole plug system. The proposed method is particularly suited to low pressure reservoirs which cannot be
5 underbalanced using a fluid medium.

The invention further provides an apparatus for use in the start up of production of hydrocarbon from a well having a casing and which well has a hydrostatic head of liquid in the well during drilling which apparatus includes,

10 a tubular member of smaller dimension than the casing for insertion into the well casing to define a chamber and a flow conduit;

means for sealing the chamber from the environment;

gas supply means attached to the chamber to supply gas
15 under pressure to the chamber;

fluid flow means to allow liquid displaced from the well to flow through the flow conduit and be collected; and

means to perforate the casing.

Although the basic apparatus is ideally applied in a
20 production start-up scenario, as mentioned above the invention is also applicable in re-working of previously exploited sites.

Apparatus for underbalancing a well comprises a tool which according to the invention, includes a body adapted to
25 be removably inserted in a well head tree and having

discrete fluid channels therein, one of said channels having at one end thereof a fluid tight coupling for attachment of a controllable gas supply, the other of said channels having a fluid tight coupling to vent fluid to a collector, said
5 body further having means for attaching a length of tubing for insertion into a well tubing to serve as a means of exchanging fluid within the well tubing for gas and thereby adjust the pressure in the well tubing.

Preferably, said tubing attachable to said body is
10 provided with a foraminated bull nose distal end.

The present proposal offers a quick, technically simple and cheap opportunity for underbalancing a well with a minimum risk of environmental discharge into the sea. In addition to offering financial benefits for new
15 installations, the invention offers a simple cost effective way of ensuring full hydra testing is carried out on wells requiring re-entry thereby minimising the risks of hydrate formation and reducing re-entry costs. The present invention is also ideally suited to low pressure reservoirs which
20 cannot be underbalanced using a fluid medium.

Brief Description of the Drawings

Embodiments of the present invention will now be described by way of example only with reference to the following drawings, in which:

25 Fig. 1 is a diagrammatic representation of a reservoir section being drilled;

Fig. 2 is a diagrammatic representation of a casing and a cemented liner after insertion into the hydrocarbon well;

Fig. 3 is a diagrammatic representation of the well after completion;

5 Fig. 4 is a diagrammatic representation of the underbalanced well in accordance with the present invention;

Fig. 5 is a diagrammatic representation of a perforated underbalanced well in accordance with the present invention; and

10 Fig. 6 is a diagrammatic representation of the underbalanced well during the production phase of the well.

Detailed Description of Exemplary Embodiment

Referring to Fig 1, there is shown schematically a well borehole 10 being drilled with a conventional drill bit 20 and a drill pipe 40 to the depth of the reservoir section 20. Casing 30 is placed inside the borehole 10 as a lining to secure the hole and prevent the walls from collapsing. The casing 30 is run soon after drilling the first hundred metres or so of the hole 10. At this drilling stage, the well 10 is full of kill weight mud. This means that the hydrostatic column of mud is greater than the reservoir pressure. This is illustrated by calculating the pressures using the following formula:

$$p = 0.052 \text{ gh,}$$

where p is in psi;

g is in pounds per gallon; and

h is in feet.

Where the reservoir depth is 4000 feet, as indicated by
5 point P, and the mud weight is 11 ppg (pounds per gallon),
then the hydrostatic head equals:

$$0.052 \times 11 \times 4000 = 2288 \text{psi hydrostatic}$$

As the reservoir pressure at 4000 feet is equal to 2000 psi,
this equates to an overbalance of 288 psi. This overbalance
10 keeps the well 10 stable and prevents the hydrocarbon being
produced into the well 10.

Sections of the casing are coupled together as with
drill pipe, but they may be welded together, threaded or
interlocked, and when the string reaches the required depth
15 it is cemented in position, as shown in Fig. 2. With the
drill pipe in place an annulus is formed, up which drilling
fluid and cuttings may travel to the surface. A deep hole
will need several concentric runs of reducing diameter to
make up a casing programme

20 Primary cementing is the first job in a casing
cementing programme, which takes place soon after the casing
has been run. After the drill string has been removed cement
is pumped down the inside of the casing to clear the hole of
mud. A cementing plug is then inserted, followed by drilling
25 fluid, which forces the cement to the bottom of the hole and

up into the space between casing and hole, or between casings, until it reaches the surface along with any remaining mud. This is known as cementing up. When set, the cement 60 keeps the casing 50 in place and secures the hole
5 against the ingress of unwanted fluids by filling the annular space between the casing and the bore wall. This provides an added barrier to the well over and above the mud column used in the drilling phase. The unperforated cemented casing 50 also retains the reservoir pressure at the
10 reservoir depth. As a prelude to the production phase of operation of the well, the well bore fluid is exchanged from a relatively high density drilling mud to a lower density completion fluid 110 such as a brine containing for example sodium chloride or calcium chloride which has a weight of
15 10ppg. This is achieved using conventional clean-up techniques employing drill pipe and casing scrapers. The blade type or wire brush scrapers are used as a mechanical means to scrape the internal wall of the casing down to the bottom of the well. This process removes any mud cake, which
20 has built up on the casing well by pumping sea water into the wellbore until the fluid returns have reached the required level of cleanliness. Once the well has been cleaned, the pre-filtered completion brine is circulated into the wellbore. By reducing the weight of the fluid in
25 this manner, the hydrostatic head is reduced further as the following calculation illustrates;

$$0.052 \times 10 \times 4000 = 2080\text{psi hydrostatic}$$

The fluid column is still overbalanced by 80psi at this stage.

As shown in Fig. 3, the well 10 is completed by installing a down hole safety valve 70, a packer 80, connection tubulars 90, and a wellhead 100. After completion, the well is still overbalanced by 80psi.

After completion of the well has been successfully carried out, the well is in a condition which enables it to be underbalanced with a view to facilitating production. Referring to Fig. 4, it can be seen that the underbalance is achieved by running 600 feet of slim pipe 120 into the completion zone 130. Nitrogen 150 is then pumped under pressure into the well to remove the upper part-volume of the fluid column down to a level 160 at the end of the slim pipe 120. The pump pressure required through the system is a function of how deep the slim pipe 120 is run into the well and the density of the completion fluid 110. The pressure range is a function of the differential pressure at the drilling tool 20 and the rate at which the nitrogen is being pumped. The return line 140 for the completion fluid/nitrogen to the surge tank on deck (not shown) is choked back. This ensures that a back pressure is maintained during the nitrogen pumping operation. The system can be operated from a minimum pressure of 50psi to a maximum operating pressure of 5000psi. The following calculation shows how the well is underbalanced;

$$4000 \times 10 \times 0.052 = 2080\text{psi hydrostatic}$$

$$600 \times 10 \times 0.052 = 312\text{psi}$$

this produces a hydrostatic head of 1776psi

As the reservoir pressure is equal to 2000psi, this produces
5 an underbalance of 223psi. The fluid returns 140 removed by
the nitrogen 150 can be monitored to ensure the correct
underbalance has been achieved. The underbalance can also
be verified by the pressure reading.

After the well has been cased, cemented and serviced,
10 each productive horizon is completed by making permanent
contact between it and the well bore, and installing tubing
and the appropriate equipment for controlling fluid flow.
Contact with each horizon may be achieved directly or by
perforating the casing, as shown in Fig. 5, using wireline
15 guns 180. Completions may be single or multiple completions
and separate tubings are run according to the number of
productive zones. This causes the fluid level 160 to rise,
offloading the well in the process.

Fig. 6 shows the well in the production phase after a
20 production tree 190 has been fitted.

The method described eliminates the complex mechanisms
and procedures utilised by existing methods. Benefit is
gained from the fact that the present invention can be used
to underbalance a well extremely quickly and at a far lower
25 cost than can be achieved using existing methods.

The example described is given by way of example only, and is not intended to limit the scope of the invention in any way.

Claims

1. A method of initiating production of hydrocarbons from
a well including a shaft with a casing or lining therein;
and a flow conduit located within the casing or lining;
5 which well has a column of liquid to provide a hydrostatic
head, which method comprises:

inserting a tubular member inside the casing or lining
to a required depth in the liquid to define a chamber;

sealing the chamber from the outside environment;

10 causing a gaseous material to flow into the chamber to
create a pressure differential between the chamber and the
outside environment, and so cause the liquid in the well to
be displaced and flow along the flow conduit;

collecting the liquid displaced from the well; and

15 perforating the casing to enable the hydrocarbon to
flow.

2. The method according to claim 1 wherein said gaseous
material is an inert gas.

3. The method according to claim 2 wherein said inert gas
20 is nitrogen.

4. The method according to any of the preceding claims
wherein said displaced fluid is an aqueous completion
fluid.

5. The method according to claim 4 wherein said completion fluid is sodium chloride, calcium chloride or brine.

6. The method according to any of the preceding claims
5 wherein sealing the chamber includes cementing said casing or lining in place filling the annular space between the casing or lining and the bore hole.

7. A method of underbalancing a well which does not have sufficient pressure to provide flow from a reservoir to be
10 tapped, by introduction of a gas to displace fluid from tubing forming part of the well which method comprises:

installing in an upper part of the well tubing remote from the reservoir underbalance means for pumping fluids separately therethrough and an associated tool tubing of
15 smaller bore than the well tubing and of pre-selected length capable of penetrating into the well tubing to a pre-determined depth to permit exchange of fluid in the well for gas;

locating the tool tubing within the well tubing;

20 connecting the tool and its tubing to permit fluid flow therein;

providing a controllable gas supply to said tool; and

operating the tool to deliver gas and displacing fluid from the well tubing by means of said gas to achieve underbalance.

8. The use of the method in accordance with any of the
5 preceding claims to initiate production of hydrocarbons from a new well, or a suspended well, or a re-entered well.

9. The use of the method according to claim 8 with a downhole plug system.

10. The use of the method according to claim 9 wherein the
10 well has been pre-perforated.

11. The use of the method according to claim 9 wherein the well uses slotted liners

12. Apparatus for use in the initiation of production of hydrocarbon from a well having a casing and which well has
15 a hydrostatic head of liquid in the well during drilling which apparatus includes:

a tubular member for insertion into the well casing to define a chamber and a flow conduit;

means for sealing the chamber from the environment;

20 gas supply means to supply gas under pressure to the chamber;

fluid flow means to allow liquid displaced from the well to flow through the flow conduit and be collected; and

means to perforate the casing.

13. Apparatus for underbalancing a well comprising;

a tool which includes a body adapted to be removably inserted in a well and having at least one discrete fluid
5 channel therein;

one of said fluid channels is provided at one end with a fluid tight coupling for attachment to a controllable gas supply;

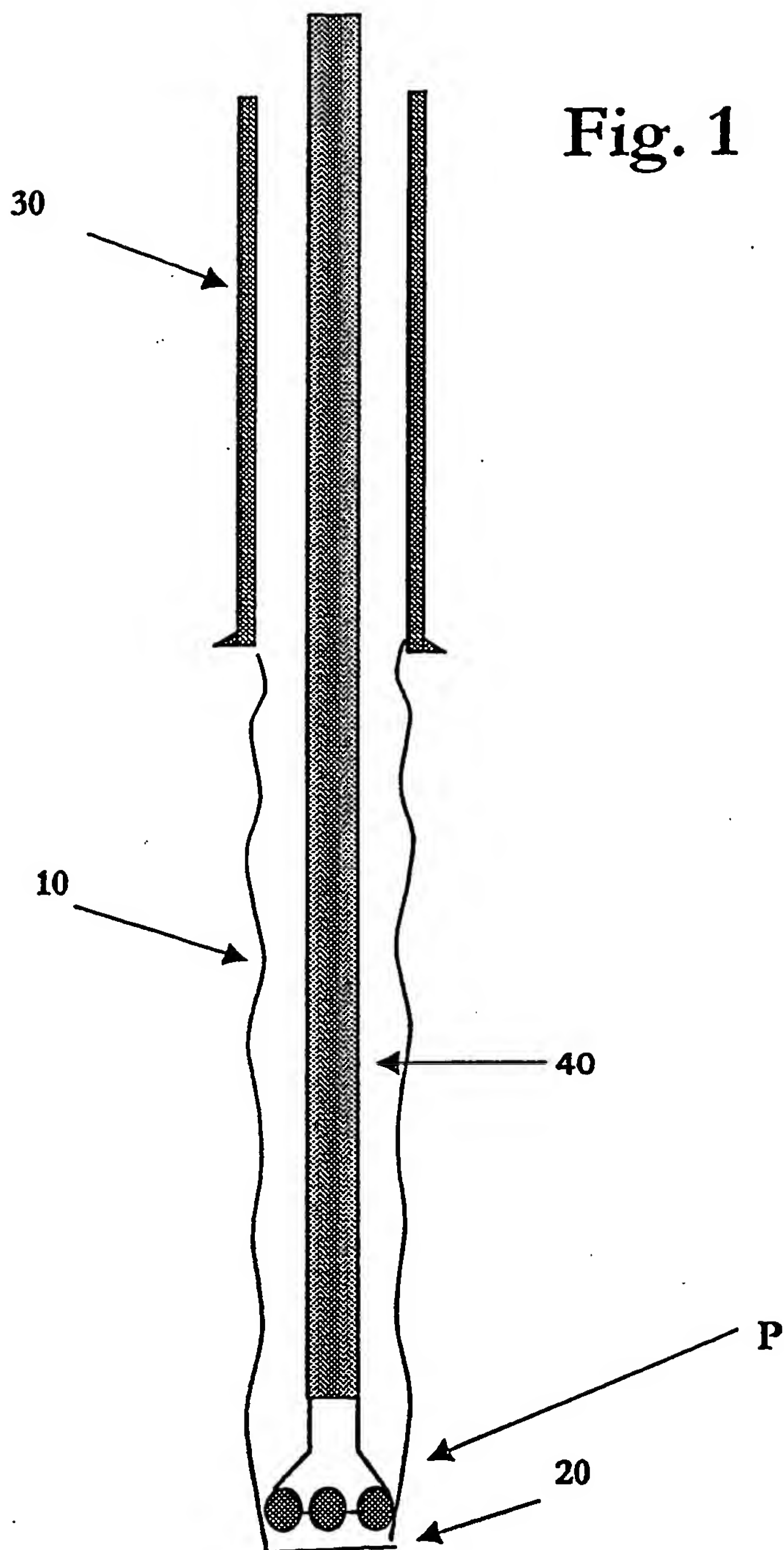
one of the other channels having a fluid tight
10 coupling for venting fluid to a collector; wherein

said body further includes means for attaching a length of tubing for insertion into the well tubing to provide means of exchanging fluids within the well and to adjust the pressure in the well tubing.

15 14. Apparatus as claimed in claim 13 wherein said tubing attachable to said body is provided with a foraminated bull nose distal end.

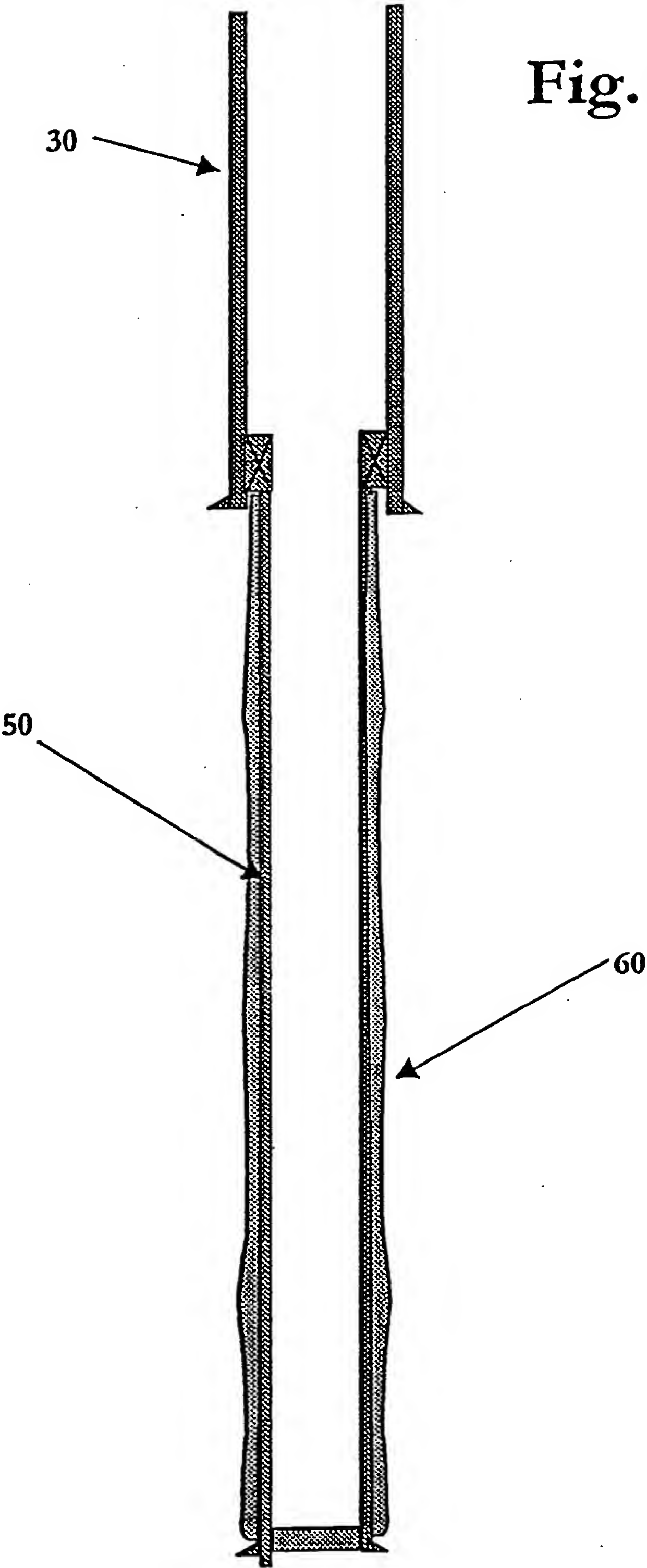
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Fig. 1

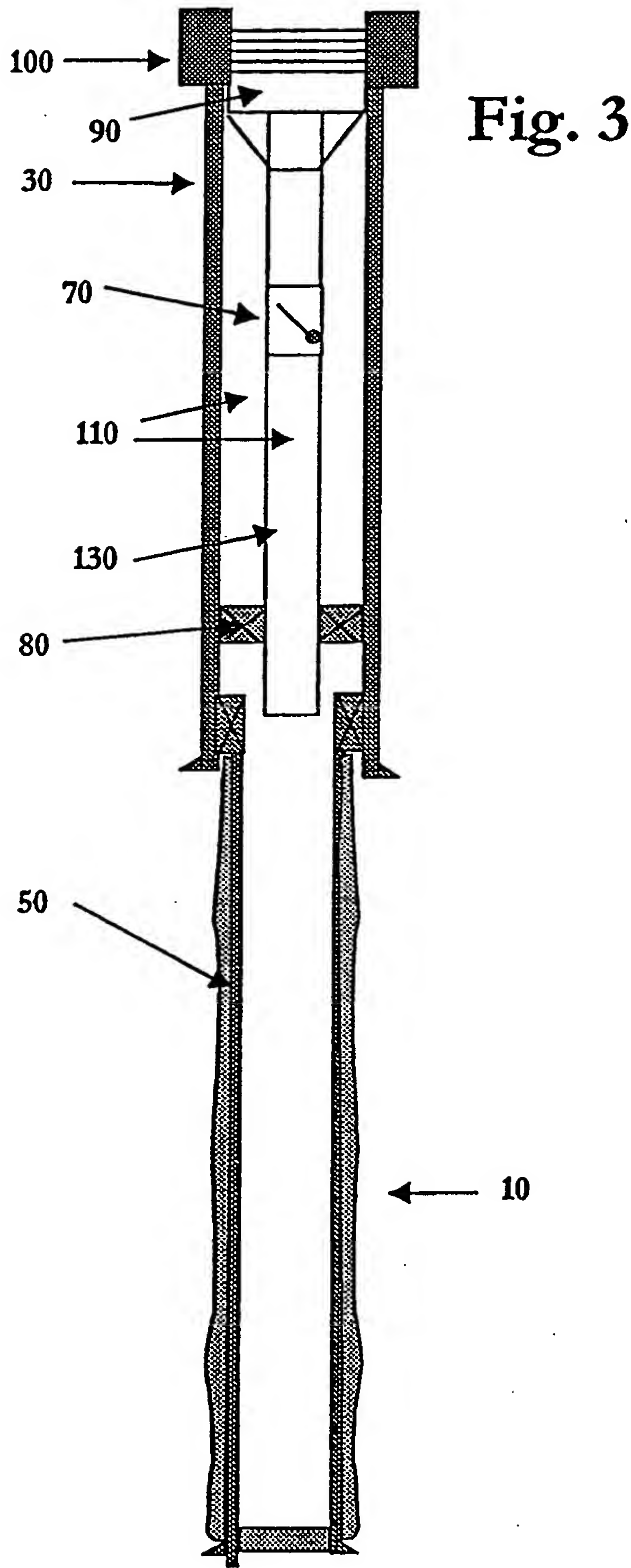


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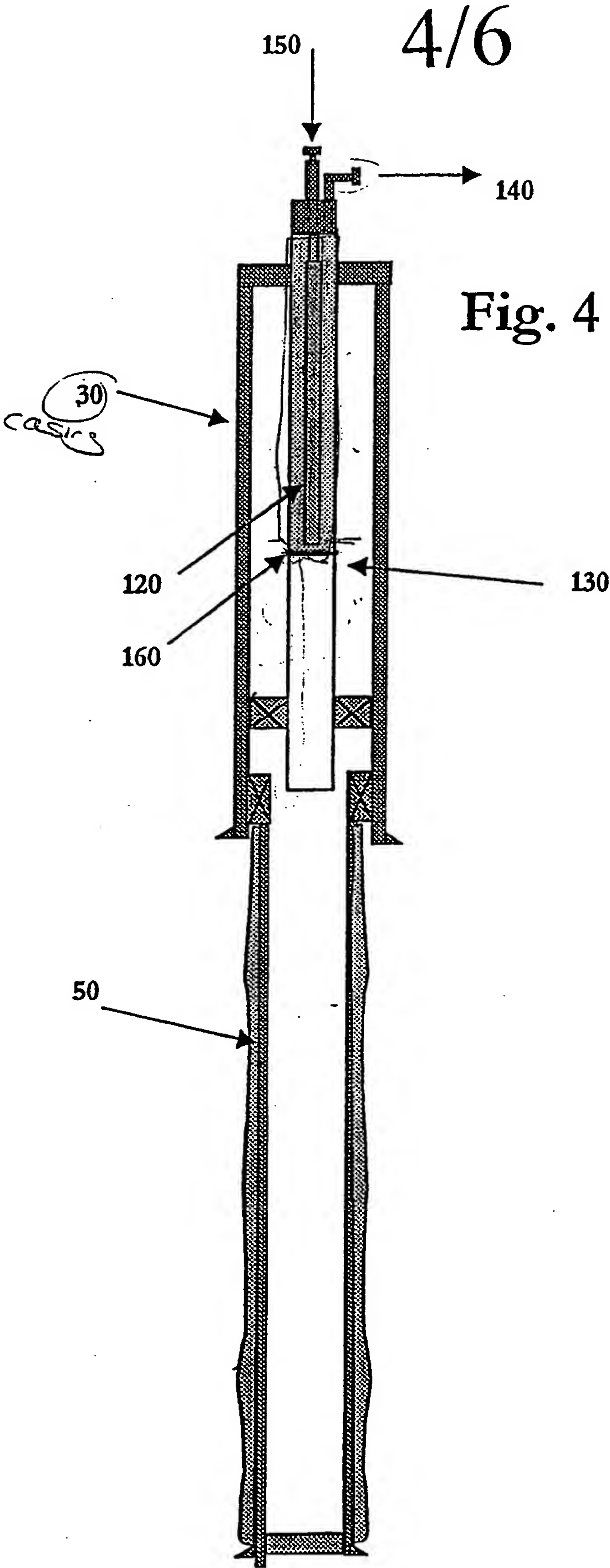
Fig. 2



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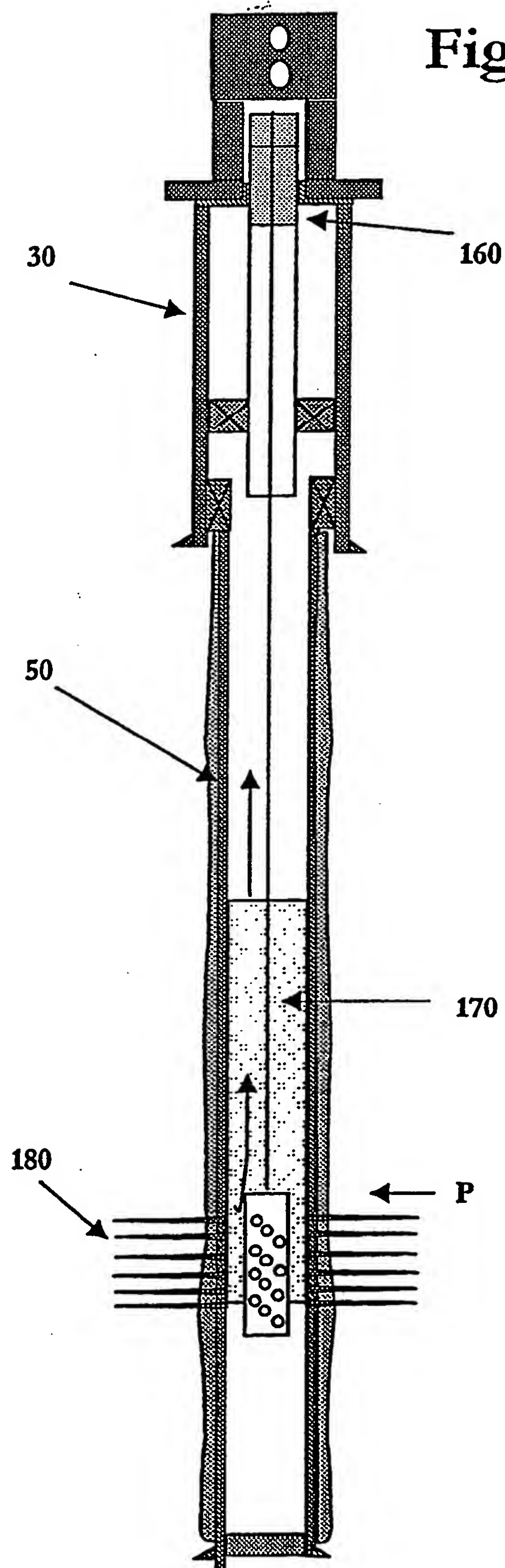


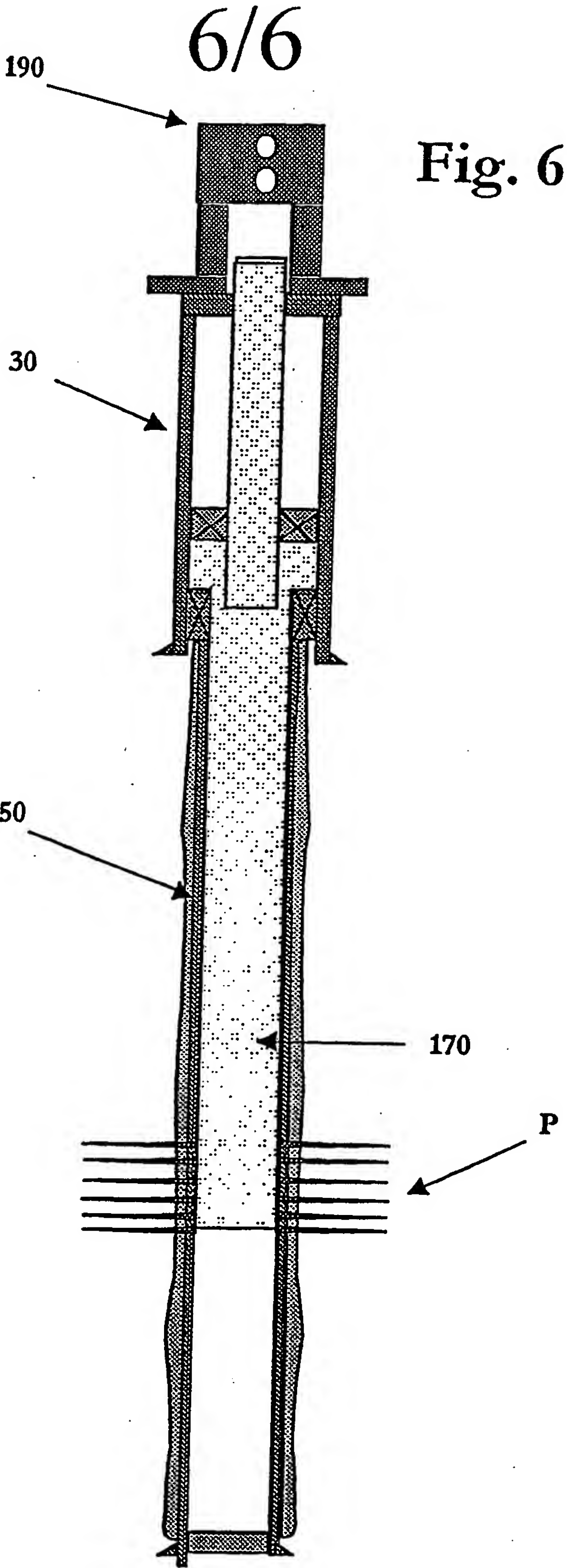
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Fig. 5





INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/03741

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B43/00 E21B21/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

TULSA, EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SCOTT ET AL.: "Air foam improves efficiency of completion and workover operations in low-pressure gas wells" 1994 SPE MID-CONTINENT GAS SYMPOSIUM, 22 - 24 May 1994, pages 219-225, XP002156494 amarillo page 220, paragr. "coiled tubing"	1-3,6, 8-13
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Y		4,5
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Y	US 4 175 042 A (MONDSHINE) 20 November 1979 (1979-11-20) abstract	4,5
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

4 January 2001

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INTERNATIONAL SEARCH REPORT

Inter nal Application No

PCT/GB 00/03741

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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